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STREET GRADES AND CROSS-SECTIONS IN ASPHALT AND CEMENT.

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PRESENTED MARCH 1ST, 1899.

WITH DISCUSSION.

Certain rules and practices in street improvements have been formulated in the larger cities, which, although desirable, cannot always be applied to similar work in the smaller ones. The size, topography, and general local conditions of a city largely determine the character of the street grades and cross-sections, and their plan of arrangement.

A slight departure from customary methods was made by the author in arranging the grades and cross-sections to be used in the recent construction of sheet-asphalt roadways and cement walks, curbs and gutters, in a part of the business district of Wabash, Ind., a small city, having a population of about 11 000. The old grades, as established, were poorly adapted for the proposed improvement, and a careful adjustment of those involved was prepared, with the object of having the finished work as substantial, convenient for use, and harmonious as the local circumstances would permit. Generally, the improvement might be regarded as unnecessary side-hill construction on a comparatively flat surface; a condition unwarranted, in view

of the original topography of the included territory, and yet not now admitting of radical changes.

The erection of many of the buildings within the limits of the improvement had preceded the adoption of any grades by the city authorities, and to this tardiness of the proper municipal officers in establishing common gradients, may be attributed much of the irregularity in the elevations of the floors of the different business rooms.

In the rearrangement of grades, the sidewalks were raised from 1 in. to 12 ins. above the floors of some dozen adjoining store rooms. The owners of the buildings affected, in several instances, waived all claims for damages occasioned by such changes, and the remaining cases were referred to the Board of City Commissioners for assessment of benefits and damages.

There are few places in the improvement where the two opposite walks on any street are on the same grade. This inequality between the elevations of opposite points on the property lines of any street attains a maximum of 2.45 ft. on a street width of 90 ft., and 1.65 ft. on a street width of 66 ft.

The prominent feature in the arrangement of the grades and sections described in this paper is what is here called the "double curb," which consisted of a lower or roadway section and an upper or sidewalk section, so shaped as to form steps from the gutter to the walk. The principal factors entering into the details of the adjustment were the determination of the location of the crown line of the roadway, the height of the exposed vertical face of the curb, and the form and amount of transverse slope of the roadway and walk.

The streets (Fig. 1) are either 90 ft. or 66 ft. wide between outside or property lines, and are paved for the full width with asphalt or cement, with the exception of one block on Market street (not shown in Fig. 1), where half the sidewalk space on either side of the roadway is paved with cement and the other half graded into lawn. On the 90-ft. street, the roadway between curb faces is 59 ft., and either walk, including the curb, is 15½ ft. wide. The 66-ft. streets have roadways 40 ft. in width between curb faces, and either walk, including the curb, is 13 ft. wide.

All roadways, exclusive of gutters, are paved with sheet asphalt consisting of a 2-in. top, and a 1-in. bituminous binder, on a 6-in. hydraulic concrete base. The walks, curbs and gutters are laid with granite-faced cement concrete; the walks being 5 ins. and the curbs and gutter 6 ins. thick.

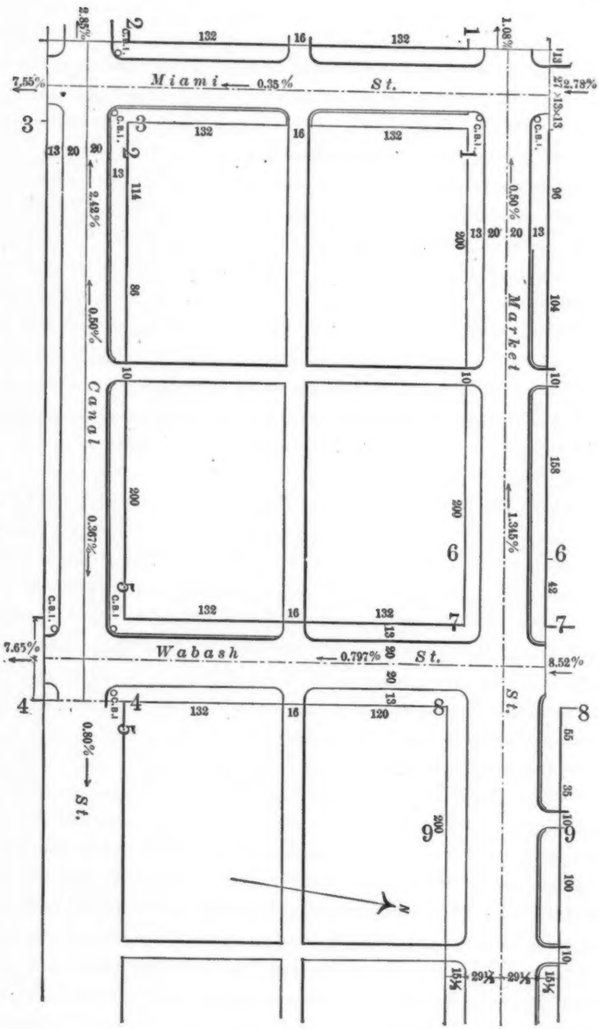
Miami St.
0.35%
Wabash St.
0.797%
Market St.
Canal St.
1.08%
2.85%
7.55%
2.78%
2.42%
0.50%
0.367%
0.80%
7.65%
8.52%
1.345%
C.B.I.

FIG. 1.

The curb and gutter throughout were combined, and constructed as a monolith, in sections 6 ft. in length. The roadway edge of the curb is turned with a 2-in. radius, and the junction of the curb and gutter was effected with a radius of 1½ ins. From out to out the combined curb and gutter measures 22 ins.; 6 ins. for the curb and 16 ins. for the gutter. The exposed vertical height of the curb varies from a minimum of 0.33 ft. to an extreme of 0.85 ft.

The double curb is composed of a lower or roadway section and an upper or sidewalk section constructed on parallel lines; the roadway face of the latter being 12 ins. from the roadway face of the roadway curb and the top flush with the sidewalk. The exposed vertical height varies from nothing to a maximum of 0.92 ft., and the edge is turned with a 2-in. radius. The lower or roadway section has a top width of 12 ins., and is the regular roadway curb increased by the addition of a 6-in. block of cement fitted into the space between the regular curb and the sidewalk curb, the top surface of the additional piece being flush with the top of the roadway curb. The exposed vertical height of the roadway section varies, as in the case of the regular roadway curb, from 0.33 ft. to 0.85 ft. This double curb was designed to be used where the height from the gutter to the top of the walk was more than 10 ins., but did not exceed 21 ins. Risers of 10 and 11 ins. in steps are rather excessive, but it was thought that the exigencies of the situation permitted their adoption in the few places where they were used.

All cut-off boxes for gas and water supply to buildings, were placed in the sidewalk space immediately back of the regular curb, and where encountered contiguous to the double curb, they were fitted into the widened portion of the lower section.

Several short stretches of good stone sidewalks had been constructed by property owners under previous city ordinances, and after some adjustment were allowed to remain. They comprised the north walk on Canal Street, from Miami Street to Wabash Street, and several small lengths on both sides of Market Street, between Wabash and Huntington Streets. Those on the north side of Market Street had been paved to a width of only 12 ft., thus necessitating a widening of several feet.

Frequently, in street construction, where the side lines are on different gradients, one gutter is placed higher than the other, and the transverse form of the roadway made either on a straight line between the two gutters, or in the form of half an arc, the chord of which is

OUTLINES OF CROSS SECTIONS OF STREETS.

ALL MEASUREMENTS IN FEET.

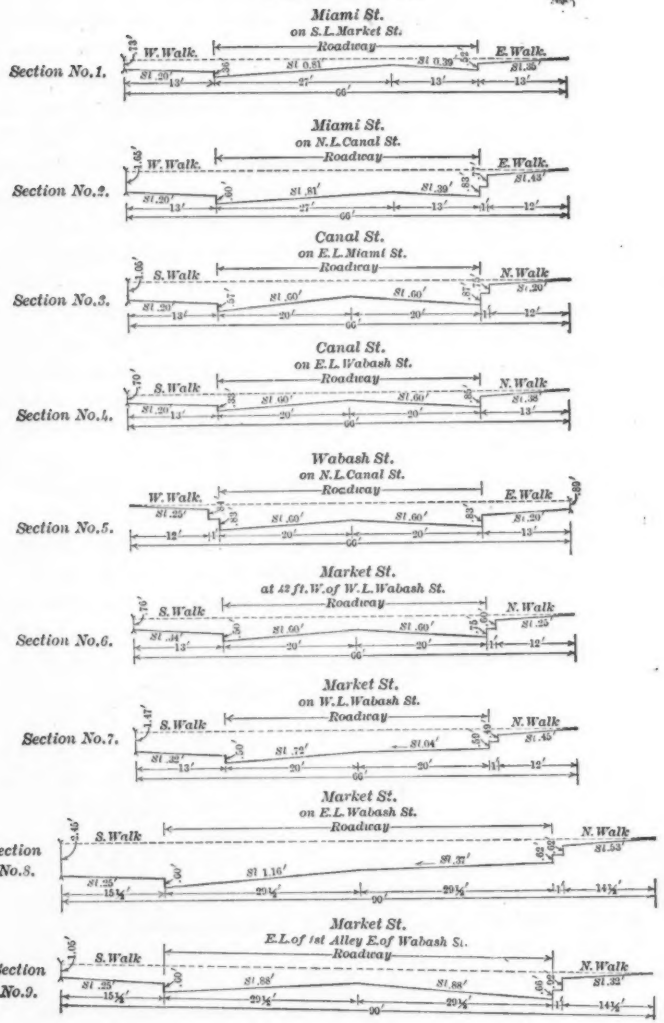

FIG. 2.

double the width of the roadway. When the former is used, sags or depressions have a tendency to develop in the pavement, especially where the roadway is wide, and with either one, the objection might be raised, that carriage and street car travel are not best accommodated. It was decided to preserve a crown line within the roadway throughout this improvement, due consideration having been given to other conditions; and to keep it preferably in the center; but, as an expedient, in one block of pavement on Miami Street, the crown line was shifted 7 ft. from the center toward the high side of the street, as shown in Sections Nos. 1 and 2, Fig. 2. With this single exception the crown line was maintained in the center of each roadway.

The three usual forms for roadway crowns are, the parabolic and circular curves, or a combination of either one with tangent sides. Of these, the first two are nearly always alike, while the last may be arranged quite differently from either. The form used by the author was a parabolic curve, and yet, for all practical purposes, it might be called the segment of a circle, since a calculation of both curves shows their corresponding ordinates to be almost identical where the proportion of rise to span is so small as prevails in the construction of city pavements. The distance from the edge of the gutter to the crown line was divided into eight equal parts, the division points being numbered consecutively from "0" at the crown line, to "8" at the gutter, and the formula, as deduced for determining the ordinates from the surface of the pavement to a horizontal line level with the crown point, is as follows:

Ordinate at the crown point 0 = 0
" " 1 = 0.0156 C or $\frac{1}{64}$ C
" " 2 = 0.0625 C " $\frac{4}{64}$ C
" " 3 = 0.1406 C " $\frac{9}{64}$ C
" " 4 = 0.2500 C " $\frac{16}{64}$ C
" " 5 = 0.3906 C " $\frac{25}{64}$ C
" " 6 = 0.5625 C " $\frac{36}{64}$ C
" " 7 = 0.7656 C " $\frac{49}{64}$ C
" edge of gutter " 8 = 1.0000 C " $\frac{64}{64}$ C

in which C equals the crown, for the distance specified.

The amount of crown of each roadway from the face of the curb to the crown line is 3% of the horizontal distance between the two points named. Of this amount the gutter has a uniform slope of 0.08 ft., in its width of 16 ins., and the remainder is the rise or crown for the

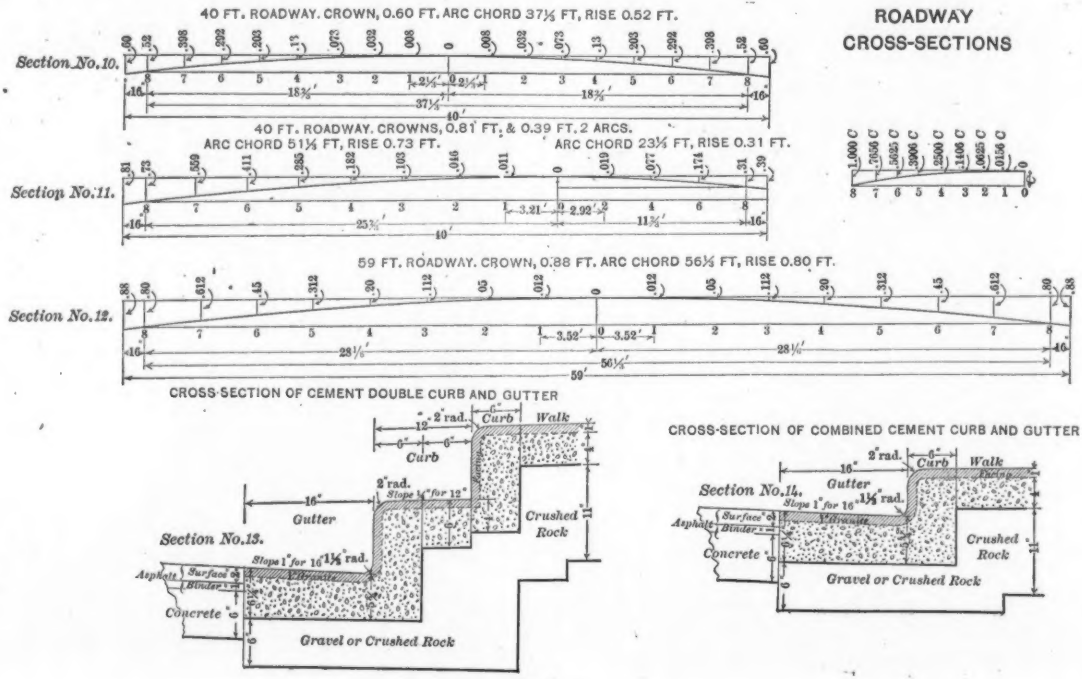
ROADWAY CROSS-SECTIONS
40 FT. ROADWAY. CROWN, 0.60 FT. ARC CHORD 37½ FT, RISE 0.52 FT.
Section No. 10.
40 FT. ROADWAY. CROWNS, 0.81 FT. & 0.39 FT. 2 ARCS.
ARC CHORD 51½ FT, RISE 0.73 FT.
ARC CHORD 23½ FT, RISE 0.31 FT.
Section No. 11.
59 FT. ROADWAY. CROWN, 0.88 FT. ARC CHORD 56½ FT, RISE 0.80 FT.
Section No. 12.
CROSS-SECTION OF CEMENT DOUBLE CURB AND GUTTER
Section No. 13.
Curb
Walk
Gutter
Crushed Rock
Asphalt
Surface
Binder
Concrete
Gravel or Crushed Rock
CROSS-SECTION OF COMBINED CEMENT CURB AND GUTTER
Section No. 14.

FIG. 3.

asphalt portion. In the case of a roadway 40 ft. in width between curb faces, with the crown line in the center, the total rise or crown is 0.60 ft., and the crown in the asphalt portion which is included between the gutter edges is 0.52 ft. This latter rise, as before stated, is proportioned on the form of a parabolic curve.

The crown and gutter lines in each block of pavement are on parallel longitudinal grades throughout, excepting the small deviations made on Market Street on either side of the Wabash and Market Street intersection. These roadway grades range from a minimum of 0.35% to a maximum of 2.42 per cent.

The cross-slope of the sidewalks is on a uniform inclination from the property lines of the streets to the curbs, and varies in amount from 0.015% to an occasional 4% grade.

The plan, Fig. 1, exhibits the dimensions of the streets, the location of the regular and double curbs and the longitudinal grade of the roadways. The two large similar figures on the same line refer to the numbers of the detailed outline sections shown in Fig. 2.

Outlines of nine different cross-sections of the streets are represented in Fig. 2, indicating the amount of slope given to the roadway and walks, together with the excess of elevation of one walk over the other at the location cited. Sections Nos. 10, 11 and 12, in Fig. 3, are the forms of crown for the several roadways, with the ordinates given in decimals of a foot, as calculated by the parabolic formula. The form for the 40-ft. roadway having the crown line in the center, is shown in section No. 10, the curve corresponding closely with a circular arc having a radius of 335.30 ft. Section No. 11 is the form for the 40-ft. roadway having the crown line shifted 7 ft. from the center, and contains two curves. The short one on the right has a rise or middle ordinate of 0.31 ft., a half chord of $11\frac{3}{4}$ ft., and corresponds closely with a circular arc having a radius of 219.68 ft.; the longer one on the left has a rise or middle ordinate of 0.73 ft., a half chord of $25\frac{3}{4}$ ft., and corresponds with a circular arc having a radius of 451.58 ft. The form shown in section No. 12, was used for the 59-ft. roadway, the corresponding circular arc having a radius of 496.25 ft.

The double curb and gutter, and the combined single curb and gutter are shown in sections Nos. 13 and 14, respectively.

Two views of Wabash Street, taken before and after the construction of the improved pavement, are shown on Plate I.

PLATE I.
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WOODS ON STREET GRADES AND CROSS-SECTIONS.

FIG. 1.

FIG. 2.

DISCUSSION.

JAMES OWEN, M. Am. Soc. C. E.—In regard to the question of crown, the speaker's ideas are somewhat decided. It is his desire to impress upon everybody the fact that the roadway itself is made primarily for wagon travel, and that, *per se*, a level cross-section is much more advantageous for such travel than any other cross-section. A departure therefrom can only be tolerated because there are overcoming disadvantages against it. The original country road was piled up probably 2 ft. in the center so that the water could be shed to the gutters. As the character of highways has been improved, the crown has been gradually decreased, until, with the improved pavements of to-day, it seems to the speaker that the crown is scarcely a matter of consideration, and in his practice, in both asphalt and brick pavements, he has reduced it to about 3 ins. in, say, 40 ft. Mr. Owen.

The only advantage of the crown is to shed the water to the sides in order to avoid the wash of the perishable material of the roadway and the damage ensuing therefrom. For a permanent, smooth roadway, either of granite blocks, brick or asphalt, no argument can be advanced in favor of any crown at all, except such as is needed to shed the water, at the proper point, away from the street entirely. In fact, the question of using the roadway itself, from curb to curb, as a gutter, is now quite often considered; and the question of economy in constructing storm sewers is being considered in that light. For instance, on a side hill, with streets at right angles to the slope, it is economical to use the streets themselves as gutters and discharge the water into the storm sewer at each cross street, the latter being provided with a crown in order to divert the water into the sewer. The speaker thinks that practice is going to be more in vogue than it has been.

In considering the elimination of crown as much as possible from street construction, it will be seen that these difficulties will disappear entirely. The speaker agrees with Mr. Tillson that he could have solved the problem without the crown, and could also have avoided the steps in the gutter line.

The relation between the roadway and the depth of the gutters is purely arbitrary. In the business part of Yonkers, two or three years ago, the speaker noticed that, in the improved streets, the sidewalks were from 18 ins. to 2 ft. above the roadway. That, of course, had come about from the fact that the original grade was being altered, and, in permanent improvements, some kind of a grade had to be established, without relation to the sidewalks. The result was that the sidewalk was adapted to the improvement of the house, and it would have been detrimental to the property to cut the sidewalks down; that

Mr. Owen. the sidewalk, being 2 ft. above the street, offered no practical disadvantage, and that wagon travel could be more evenly handled with a sidewalk 18 ins. high than with one only 8 ins. high. A person can step out from a carriage more easily, and can more readily transfer freight to or from a wagon when the sidewalk is 18 ins. high than when its height is only 8 ins., and in this instance the foot travel on the spaces between the cross streets is very small. By making proper arrangements at the street intersections for the accommodation of foot travel passing from the sidewalk to the street, no practical or permanent disadvantage will result in having the sidewalk higher than the stereotyped 8 ins. Furthermore, the saving is a disadvantage, in any way it can be considered, both by stepping from a carriage a larger distance from the sidewalk and also in carrying freight over that space.

The question of the relation of the sidewalk on one side of a street to that on the other is continually arising. The speaker has constructed roadways in which there was a difference of 4 ft. in the elevation of the sidewalks. Of course, that would not be considered an ideal construction, but it had to be used. In such cases a standard curb was adopted, and the crown of the roadway was placed about 6 or 8 ft. from the center toward the higher side.

Mr. Ulrich. D. ULRICH, Assoc. M. Am. Soc. C. E.—In constructing asphalt pavements the speaker's experience has been limited, and has generally been in localities where no curb lines have been established. For that reason he has had no trouble in making the crown suit the width of the road, and has in nearly all cases made it about 4 ins. for a 60-ft. roadway. In constructing macadam roads, however, he has ordinarily made it somewhat higher. For a 20-ft. road the crown was generally made 4 ins.; for a 30-ft. road, 6 ins.; and for a 40-ft. road, 8 ins.

Mr. North. EDWARD P. NORTH, M. Am. Soc. C. E.—In what is now the Borough of Manhattan, in the City of New York, under the old charter, the Water Purveyor had charge of all new paving, repaving and repairs to pavements. New pavements, and all grading, regulating, curbing and flagging, were paid for by assessments on the property benefited. All repaving and repairs to the pavement, except those due to openings in the streets made by plumbers or companies having pipes or conduits under the pavements, were made by the city and paid for out of appropriations.

City ordinances require sidewalks to have a rise of 1 in. per 5 ft, from the curb. The lower part of the city is mostly without official grades, but, commencing about at Houston Street, grades have been established. It has not, however, been established whether such grades refer to the curb stones or the middle of the streets. This uncertainty is, at times, a matter of convenience to the engineer who wishes to improve the profile of a street that is to be repaved, as it allows a comfortable working latitude.

Mr. North.

There is a noticeable exception to this statement, viz., the streets joining the Riverside Drive. Here, the grades were established by the Park Commissioners for the curbs, both on the drive and on the streets back to the house lines. Unfortunately, they were substantially level, although the same authorities had established quite steep grades on the streets (in one instance, though not adjoining the Riverside Drive, a grade of 18%, which is thought to be the maximum). As any departure, in either paving or curb setting, from the established grade, is liable to result in vacating the assessment, these level areas of 18 to 20 ft., joining, say, a 10% rise, have to be retained, and are objectionable.

There is also a troublesome practice by those who are called "skin builders," who, contracting to build a house with certain dimensions between the floors, avoid the excavation of 2 and sometimes 3 ft. of rock, by establishing a curb grade suited to their work and also by increasing materially the slope of the sidewalk. This swindle is generally undetected, particularly on unpaved streets, until the house is paid for, and, in some instances, causes considerable trouble and dissatisfaction to the property owner, as the curb is generally reset on the proper grade when the street is paved, which either necessitates relaying the sidewalk in front of the property, or an approximation to the practice described by the author.

Except as in the instances cited, the engineer in charge of the streets in the City of New York probably has as little trouble with grades as in any other city or town. No ordinance governs the depths of gutters, but they are called for in all streets; nor is any crown specified in the city ordinances.

On taking charge of the paving in what is now the Borough of Manhattan, with the office of Water Purveyor, it was decided to make the crown of all asphalted streets, with curbs at equal elevations, $\frac{1}{100}$ of the distance between curbs, and the normal depths of gutters between $3\frac{1}{2}$ and $4\frac{1}{2}$ ins. The crown adopted, combined with the low curbs, gives a street of apparent civilization and luxury; the high crown being a survival from the pathmasters' "turnpiking" with heavy soils; and the deep gutters antedate sewers. Some of the asphalting companies objected to these unprecedentedly flat transverse profiles, as the cost of thorough maintenance is, doubtless, greater than where water will run off more quickly. It was with some satisfaction that notice was taken that the French engineers had at last adopted the same rise, viz., $\frac{1}{100}$, for the wheelway of the Alexander III Bridge, drawings of which were presented at the meeting of the Society on February 15th, 1899.

No complaint has ever been made, to the speaker's knowledge, of cellars flooding through insufficient capacity of $3\frac{1}{2}$-in. gutters; so it apparently may be assumed that on asphalted streets with 4-in. gutters and sidewalks of one-half the width of the wheelway, rising at the rate

Mr. North. above mentioned, no danger to cellars is to be apprehended if the sewers have sufficient capacity to take off the water.

Objections are frequently made to longitudinal grades on asphalted pavements, futile efforts having been maintained for years by one of the city departments to confine asphalt to grades of 2½% or less. Small attention, however, is generally given to transverse grades, although every one knows that while on asphalt a horse may stumble in the line of draft, he almost invariably falls at right angles to it. As a matter of fact, it is difficult to get a horse that knows anything about asphalt to travel anywhere except in the center of a high-crowned street in slippery weather. This obvious danger from excessive transverse grades led to the suppression of the crown in streets having a transverse fall of much over 3 per cent.

The first asphalted street paved without a crown was Eightieth Street between Fourth and Madison Avenues. On Fourth Avenue the difference in elevation between curbs was 1.3 ft.; by making a 7-in. curb on the north and 4-in. curb on the south side, the fall was reduced to 1.05 ft., or a grade of 3½ per cent. The foundation was the old trap-block pavement relaid. The transverse profile at Fourth Avenue was a right line; at Madison Avenue it had a rise of $\frac{1}{100}$, and the south curb was somewhat lower than the north curb. The grades were "boned in" for 405 ft. between the two end-profiles on the center, quarter and curb lines. No settlement or distortion has been observed.

The above-mentioned practice was often modified, where the relative heights of the curbs would admit, by reducing the length of the warped surface to 150 or 200 ft. In other instances it was thought advisable to dispense with a crown for one or more blocks. In such cases there was no gutter on the upper side. No instances have come to the speaker's knowledge where sags or depressions in the foundations have developed, either with a relaid stone pavement or with a concrete foundation. In some cases, however, a crown of about 1 in. was worked in, consequent to the turnpike idea, as aforesaid.

Experience in the City of New York is decidedly against concrete curbs. While a good curb can be made of concrete, with proper materials and care, poor work cannot be prevented, and many, if not most, of the concrete curbs laid have been scamp affairs, with concrete made of cinders and plastered with a thin coating of poor cement. The wheel of a grocer's delivery wagon would cut this thin coating off, and backing a coal cart against the curb would break it. The poorest curbs were put down in the tenement house districts where the surroundings are squalid enough without the additional aid afforded by broken curbs. Fortunately, there was a city ordinance requiring stone curbs. Under this ordinance, samples of the curbs were taken to court and their construction, for a time, at least, stopped.

Mr. Owen's suggestion, that the gutter should be in the middle of

the street, is worth consideration, particularly for asphalted streets. Rain would flush the pavement more quickly, and as the transverse profile would be two right lines joined by a concave curve, instead of a convex curve increasing in rate toward the side gutters, as at present, the whole carriage-way on level streets could be made equally available for traffic, as it would not be necessary to have the transverse grade as high as 1 per cent. A single gutter in the center of the street is found in many Spanish towns, and was considered for some of the narrow streets in the lower part of the City of New York, but the ordinance calling for gutters and curbs prevented its use. Mr. North.

G. W. TILLSON, M. Am. Soc. C. E.—The speaker has been much interested in this paper, as it discusses a question which he has been studying for some years. The author has been confronted with the problem that always presents itself to every engineer who attempts to pave a street where the grades have been established by one who never expected the street to be paved, or had no idea of the proper cross-section of a paved roadway; or where a side-hill street has been built up, with no consideration for the future improvement of the street, but only according to the whims of the individual property owners. Mr. Tillson.

When such conditions exist, and the entire width of the street is to be improved, the difference in elevation of the curbs must first be reduced to a minimum, by giving the sidewalks on the high side the maximum, and on the low side the minimum, allowable slope. In the same way, by applying the maximum gutter to the high side, and the minimum to the low side, the difference in elevation of the gutters is made as little as possible.

The best cross-section for the roadway itself is now to be considered. Some engineers would make this a straight line from gutter to gutter. The speaker does not think this is right. Any little variation from a true plane, caused either by imperfect work or the action of travel, will show much more plainly than when the surface is slightly curved. It is also better to prevent all the water from running transversely across the street. By locating the crown of the street on the quarter, instead of at the center, and by giving a slight rise from the higher gutter to the crown, these two difficulties are overcome, the difference in elevation is but slightly changed, and the distance in which to overcome it is made considerable.

The author has adopted 0.33 ft. for a minimum and 0.85 ft. for a maximum gutter. These figures agree very closely with the speaker's ideas; but a gutter involving a step of 10 ins. should be used only in very extreme cases, and when to this is added another step of 11 ins., and the two are separated by a tread of 12 ins., the construction is bad, and should be avoided, unless it can be shown to be absolutely the best under the existing conditions. A double curb, as constructed, is expensive, unsightly and dangerous.

Mr. Tillson.

In Fig. 4 the speaker has taken five of the worst sections shown in the paper and has replatted them, and on the same base has platted the sections he would have used. The author's section is shown by a full line and the speaker's by a dotted line, the latter result being obtained by using sidewalk slopes and gutters within the limits recommended by the author.

In Section No. 5 it will be seen that by making gutters 0.66 ft. and 0.36 ft. on the high and low sides, respectively, making the crown on the quarter, and allowing a rise of 0.16 ft. from the gutter to the

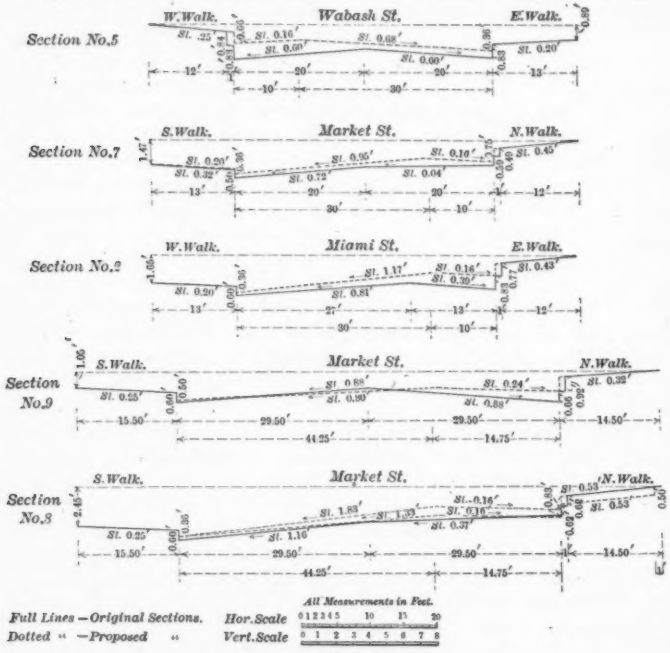

FIG. 4.

quarter, a section can be obtained which in no place has a greater slope than the author's, which has a step of 0.66 ft. instead of 0.82 ft. and which does away entirely with the double curb. On the street, the fact that the two sides are unbalanced would hardly be noticed, except by a trained eye, and for practical use this section is as good as the other.

In Section No. 7 the slope of the sidewalk on the low side is reduced to the minimum and the depth of the gutter made 0.36 ft. On

the other side the maximum gutter is taken, and the rise to the quarter is the same as used in Section No. 5. The resulting section has no slope in excess of the author's, does away with the double curb, and has a curved surface where that shown by the author is practically level, there being but 0.04 ft. fall in 20 ft. Mr. Tillson.

In Section No. 2 the gutter on the low side is made 0.36 ft.; on the high side it is placed at the top of the author's real curb, and the section is figured as in No. 7. This slope is slightly in excess of that used by the author, but not to such an extent as to be detrimental, while on the other hand it does away with the necessity of the double curb.

Section No. 9 is on a street 90 ft. wide. The low gutter is made 0.5 ft. deep, and on the high side it is placed at the top of the curb, as in No. 2. By making the quarter crown 0.24 ft. above the high gutter, a section is obtained with a slope even less than the author's, and with no double curb.

In Section No. 8 the worst conditions are encountered. The two gutters are made 0.36 ft. and 0.83 ft., respectively, and the quarter crown 0.16 ft. This gives as a section the upper dotted line, which is rather bad, but the speaker thinks that even here he would adopt it in preference to the double curb and the section shown by the author, having a slope of 0.37 ft. from the gutter to the center, and thus throwing the entire surface water to the low side of the street.

If, however, it is thought that the slope is too great, the speaker would reduce it by placing the step near the building, rather than at the curb line. The exact distance from the property line must be determined by the conditions. If, as is generally the case, a certain space is allowed to property owners for a display of goods, or for area-ways or courtyards, this step might be located at the edge of this space, with no inconvenience to any one. In this event the sidewalk would be laid on the same slope as before, but 0.5 ft. lower, and the cross-section of the street would be as shown by the lower dotted line, which the speaker thinks is much to be preferred to that used by the author.

If the latter plan were adopted, the upper sidewalk would extend some 3 or 4 ft. beyond the property line at the cross streets, and then return up the side street, running the grade out in a short distance and thus doing away entirely with the two steps at the curb. Should the gutters shown by the author be retained, the actual street would be improved by adopting the section shown by the lower dotted line.

If the above new sections should be used on a street where existing conditions were as described in the paper, no double curb would be required, and, for practical purposes, the cross-sections would be as good as those shown by the author.

Mr. Tillson. These results have been obtained by varying from the author's procedure in two ways: First, by making the crown on the quarter in every case where the difference in elevation of the curbs requires it; second, by not attempting to make the slope on both sides of the center uniform.

The speaker has used the first method for several years with uniformly good results, and is fully satisfied that, under the conditions considered in the paper, it is the proper course to adopt.

While the author has not always attained the results mentioned in the second reason, he has done so in Sections Nos. 5 and 9, and, apparently, has sought to in others, thus necessitating the use of the double curb, or a needlessly high step.

Mr. Hankinson. A. W. HANKINSON, Jun. Am. Soc. C. E.—In determining crowns for asphalt pavements in New York City, that is, in the Borough of Manhattan, a standard section is assumed of $4\frac{1}{2}$-in. gutters, with a crown of $\frac{1}{100}$, and a quarter height of $\frac{1}{160}$ of the width of the roadway, thus making the proportion of crown to quarter as 8 : 5. When the curbs are not level, the gutter on the high side is deepened to a maximum of 9 ins., and if the gutters are still of unequal elevation, one-half of the difference of elevation is subtracted from the standard crown, in effect securing the standard fall of 2% from the crown to the gutter on the low side. It will be seen that in a 30-ft. roadway, with a difference of curb level of $11\frac{1}{2}$ ins., the result of following this plan will be a street with no crown at all, the pavement being on a straight grade from gutter to gutter. It seldom occurs that a greater difference in curb elevation is necessary on 30-ft. streets, as in most cases one of the curbs can be raised or the other lowered without doing very much damage to the adjoining property. The wider the roadway, the greater the difference in curb level that can be allowed; as in 60-ft. streets, the crown being $7\frac{1}{2}$ ins., a difference of 18 ins. can readily be adjusted.

The author, having the opportunity of adjusting not only the roadway, but also the sidewalk, it would seem that even his maximum difference of level of 1.65 ft. in 66 ft. could have been accommodated without the use of the stepped curb, by lowering the sidewalk on the high side. A step at the entrance of each store would be less objectionable than a continuous one at the curb for the length of the block.

Roadways of a greater width than 30 ft. have, in New York, usually a street railroad occupying 15 ft. of the street. When such railroad has no underground conduit to be used as a drain, the rails are placed on the contour of the pavement arch, as in a level 60-ft. section, the center rails would be $\frac{1}{2}$ in. below the crown and the outside rails dropped $\frac{3}{4}$ in. from the center rails. As the pavement between the rails is crowned up 1 in., this $\frac{3}{4}$-in. drop amply provides for drainage. In the case of an underground trolley with slotted conduit, the slot

rails are placed on the contour of the pavement crown and the tram rails made level if possible. Should, however, the difference of curb elevation be very great, the track is "terraced," that is, one track, that on the low side of the street, is dropped from 1 to 3 ins. from the other. By terracing the tracks and raising and dropping the outside rails $\frac{3}{4}$ in. on the high and low sides of the street, respectively, a difference of 19 ins. in curb level on a 60-ft. street has been adjusted without draining to one gutter. Mr. Hankinson.

The crowns used by the author give a much steeper cross-grade than could be safely used in New York City. His quarter height being quite high in proportion to the crown, a very sharp incline from quarter to gutter results. It may be that Wabash, Ind., is not subject to the fogs, mists and drizzling rains which make the New York pavements so slippery at times, and that a cross-grade of 3%, entirely unsuited to the climatic conditions obtaining in New York, would be eminently proper in an inland city.

J. M. Evans, Jun. Am. Soc. C. E.—Judging from the speaker's experience in street work in New York City, the double curb would find little or no place of usefulness there; the objections already mentioned in the discussion being sufficient to exclude it. One objection, however, which has not been mentioned and yet is of grave importance, is the impossibility of keeping such a step in a sanitary condition, as it would afford a convenient repository for filth. In New York City it is the custom to place hydrants, lamp-posts, fire-alarm posts, etc., very near the curb. In the double-curb arrangement these would naturally be set in the tread of the step, and the space around them would soon become filthy and unsightly. It would be more difficult to keep the step clean than the gutter, as no large flow would ever reach the step to cleanse it, while flushing and rains would thoroughly cleanse the gutter. Mr. Evans.

The methods outlined by Mr. Tillson are much more advantageous than those described by the author, and this is particularly true of the method of making the step at the stoop or area line. It is a common sight to see a house of the low-basement style where there are four or five steps leading to the basement floor, and from eight to twelve leading up to the first floor. When these houses are located on the higher side of the street, the speaker can see no reason why the sidewalk could not be depressed from 5 to 8 ins., thereby doing away with one or two of the steps down to the basement floor and adding them to the steps to the first floor. This increase in the number of steps to the first floor might be considered an objection, but hardly a serious one, as in the same block the number of steps often varies from three or four to a dozen. It would seem that it could, therefore, be easily adjusted. In business blocks, where there is a longitudinal grade, it is the custom to provide a series of steps in the coping of the area wall

Mr. Evans. which vary from nothing at the upper end to 6 or even 8 ins. at the lower end. It seems that there ought to be no serious objection to using practically the same method on transverse grades, provided the whole street can be improved thereby, and it is manifest that many streets could be improved in this manner.

Numerous petitions for improved pavements are made by residents, yet, so far as the speaker knows, very few of the petitioners are willing to submit to even the slightest inconvenience for the sake of improvement, much less would they be likely to submit to any lowering of the sidewalk, or anything that would touch their pocket-books. The speaker knows of instances where it was even impossible without process of law to get owners to make the slight repairs to their sidewalk made necessary by setting a new curb. It would seem, therefore, that some form of legislation would be necessary in order to provide for these adjustments, in repaving a street.

The speaker recalls an instance where a catch-basin was left stranded on the summit of a pyramid by changing the cross-section of the street at that intersection. This was caused by a difference of some 2 or 3 ft. in the curb levels. The cross-section of the new pavement was the already mentioned "straight line with 1-in. crown." What the old cross-section was, the speaker does not know, but he remembers that from 10 to 20 ins. of material was removed from the old crown, in reconstruction. This left the catch-basin in its exalted position which was determined by the unchangeable law of the sidewalks. Had the authorities been able to carry the improvement to the property line, a step at the area line would have solved the difficulty, improved the street, and kept the drainage from flooding diagonally across the street, deluging the cross-walks and overflowing the shallow gutters on the lower side of the street.

An interesting question is presented by the method of taking care of street drainage mentioned by Mr. Owen, in cases where under-trolleys are operated, for the reason that much, if not all, of the water would flow into the slot and, doubtless, cause much trouble and annoyance in operation. As to whether a city can so construct its streets as to make a storm sewer out of an under-trolley conduit is probably a question for the courts. Granted that it has such a right, it seems hardly fair to citizens and patrons of the road, to say nothing of the company, that they should be subjected to the inconvenience and irritation of blockades incident to "short circuits," "burn-outs," etc., caused by improper city drainage. In New York City, where one, from necessity rather than choice, must live far from business, and depend upon street railways for transportation, the latter should be considered as a necessary adjunct to business rather than a necessary evil.

PHILIP W. HENRY, Assoc. M. Am. Soc. C. E. (by letter).—Although the engineering problem to which this paper calls attention is not a difficult one, yet it is one which is met continually by city engineers and is seldom solved satisfactorily. This, however, is not due to its intricacies, from an engineering standpoint, but because the solution is complicated by politics and the influence of property holders. It is an exceedingly difficult task for an engineer to improve a street, where the conditions are similar to those mentioned in the paper, without arousing the determined opposition of those most nearly interested. For the sake of saving a few dollars the average property holder is willing to allow any kind of a grade to be established; and he objects most strenuously to any plan which will cause him to raise or lower his sidewalks or alter in any way his buildings, no matter how old or dilapidated they may be, or no matter how much the improvement may benefit his property eventually. It follows, therefore, that a city engineer is seldom able to carry out his own convictions in establishing a street grade, unless he is willing to make a determined fight, or use all the persuasive powers at his command. In Wabash, it appears that either the engineer's persuasive powers are highly developed, or else the property holders there are unusually enlightened, for the owners of the buildings affected, in several cases, waived all claims for damages occasioned by the change of grade. Mr. Henry.

It also appears that the author did not attempt too much in improving the grade of the street. The change from the old condition was radical, but at the same time it was no greater than the circumstances warranted. The difference in level between the two sidewalks was met in a somewhat novel manner, by putting in a step on the upper side of the street. It is seldom that this construction is used, and it could doubtless be introduced in other cities to advantage. Its chief disadvantage is that it lessens the width of the roadway, and on a narrow street this would, of course, be objectionable. The ample width of the Wabash roadways allowed this construction, with excellent results. The illustrations on Plate I show what a decided change was made in the appearance of the street by the improvements described in the paper. To one who saw the street before and after the improvement, the change is even more marked than that shown in the photographs.

To return to the details brought out in the paper: It does not appear why the crown was placed in the quarter in Sections 1 and 2, and not in Sections 7 and 8. It is generally objectionable to have all the water drain to one side of the street, as shown in the two latter sections. It would also seem that in these two sections each step could have been made 0.85 ft., the greatest limit, and thus have reduced considerably the slant of the street from one gutter to the other.

Although the property holder has undoubtedly been put to con-

Mr. Henry. siderable expense by the radical change in sidewalk grade, yet it is obvious that any less radical treatment would have given a patch-work effect to the street, which would have been a continual source of annoyance. There are too many streets in prominent cities which are anything but creditable to the engineers who have established the grades. This is generally due to poor engineering talent (if any engineer was employed at all), in laying out the street at the start, for many streets were originally country roads which no one foresaw would one day require paving. By the time the street had arrived at the dignity of a pavement, buildings had been erected at different grades on each side, so that the engineer who had the improvement in charge was at his wits' end to know the best way to deal with the problem. In solving this problem no general rule can be laid down, but each case must be treated by itself, taking into account the many different questions which are involved. Among these questions are width of street, value of real estate and improvements affected, amount and kind of traffic, probable increase in real estate values and probable increase in traffic. These questions are being met every day by municipal engineers all over the country, and are being solved in a better and more satisfactory manner than ever before. There is no doubt that the city engineer of to-day is the superior of his predecessor of twenty years ago, and brings greater talent and broader knowledge to bear on the questions which are continually before him. It is to be hoped that the paper will bring out discussions from engineers who, from practical experience, are able to give much interesting and profitable information to the profession.

Mr. Harley. A. F. HARLEY, M. Am. Soc. C. E. (by letter).—The problem of street grades and cross-sections is, perhaps, one of the first that confronts a city engineer, and is one in which, between his own judgment and the wishes of the various property owners, he is likely to find trouble.

In considering the subject, great difference should be made in the treatment of business and residence streets. Good renting property on business streets should be provided with such sidewalk grades in front of the various stores as to cause the pedestrian to literally roll into the store he may be passing. No such thing as a step should ever be provided near the building line, but if the grade of the sidewalk is not flush with the floor level, the entrance to the store should be "bayed," and a cast-iron foot-plate, connecting the two elevations, should be set in. On business streets it would not be objectionable, if it were found absolutely necessary, to maintain a sidewalk grade even 18 ins. above the gutter. We know that when this is the case, the street, or rather the original surface of the ground, has invariably a hill-side cross-section, and at each end of the block the grade at intersecting streets would make a tread from the sidewalk to the gutter of not over 6 or 8 ins.

Mr. Harley.

It is the writer's observation that store-keepers prefer this high curb, as it requires pedestrians, ladies especially, to promenade the full length of the block and pass other stores, while intending to visit only one in the row. Then, again, the facility for unloading, already mentioned by Mr. Owen, is a point well made.

A municipal engineer should always remember that the great majority of the citizens walking over a street surface do not carry in their heads an engineer's eye, and, so long as the water does not remain on the surface, they could not tell which way it flowed after the rain had ceased, and especially could they not detect a hill-side cross-section, *i. e.*, one in which the summit has been shifted from the center toward the higher side, nor a warped surface that runs out in 100 to 200 ft., spoken of by Mr. North. Differences of elevation on the surface of the street paving proper, as a rule, are not detected, even when the water in the gutters on each side of the street runs in opposite directions for a short distance, as might be the case at the intersection of streets that had grades of say, 4 ins. and 4 ft., respectively.

The writer holds, with Mr. Tillson, that a street should always have some crown, to allow of slight wear to the surface, which is always most in the center, provided there is no electric railroad on the street. But on the other hand, on narrow business streets, say, 30 ft. in width, occupied for more than half their width in the center by two electric street railroad tracks, in the writer's opinion, it is an open question whether it would not be desirable to throw all the water to the center, provided it could be collected and carried off, as it would be the only moving thing that would not meet its death by being run over in crossing the track; while the surface of the street close to the curb line would be more available for vehicular travel; in fact, this gutter space would be gained. In a street railroad, especially one in which the use of the ordinary T-rail is permitted, the paving between the rails is given a crown of, say, 1 in.; thus little streamlets are formed and are compelled to run the entire length of the longitudinal grade on the street, which is bad for both the railroad and the pavement, as it is almost impossible to make water-tight joints between the rails and the adjoining pavement. By the adoption of a central gutter the necessity for making these joints absolutely water-proof is avoided. Were it not for the appearance the writer would like to see the paving between the rails concaved, instead of convexed, and cast-iron gratings having the same concavity placed over catch-basins built in the center of the track at the required intervals.

The writer does not think it would be very much to ask of street railroads using the underground electric system, to make provision in their conduits to carry off the surface water that might be led into them in this manner.

Another point is, that while a very large majority of people, in

Mr. Harley. walking or driving over a street, do not notice the grades on a continuous asphalt surface, as already stated, they readily detect the difference in the height of the curbs on the street over which they are driving; even such a small difference as 4 is to 6 ins. It would, therefore, be advisable on all residence streets to make the height of the exposed curbing the same on both sides of the street, even though the surface of the pavement may have a "hill-side cross-section" or be a "warped surface."

Mr. Andrews. HORACE ANDREWS, M. Am. Soc. C. E. (by letter).—This carefully prepared paper is of interest, and the double curb is an innovation that may be found useful where other means fail. It is much to be regretted that nothing is said either in the paper or in the discussion as to the cost of the improvement. This is certainly a factor of too much importance to be disregarded by a municipal engineer. Concrete curb with gutter attached, similar to that described in the paper, has been laid, under the writer's specifications, for 90 cents per lineal foot. It will be of interest to know whether the double curb cost twice the above amount.

The writer agrees with Messrs. Tillson and Hankinson that the second step would better have been omitted at the curb and placed near the fronts of the buildings.

Two steps might even have been used in such a location. The street once improved is apt to retain its cross-section for many years, while it would appear from the photographic views that many of the buildings will be replaced before very long and then the suggested steps in front of them could be done away with.

The relative widths of sidewalks and carriageway are closely connected with the question of economical improvement. It would seem that the 90-ft. streets would have looked better, would have amply accommodated all traffic and would have been more economically improved with 20-ft. sidewalks and a 50-ft. carriage-way, while the 66-ft. streets, with 30-ft. carriage-ways, would certainly accommodate all vehicle traffic in a place the size of Wabash. It would be much cheaper to construct sidewalks than equal areas of asphalt pavement.

The writer agrees with Mr. North as to the superiority of stone over concrete for curbs. The concrete gutter is peculiarly objectionable on account of the running joint at its outer edge; this is quite apt to wear into a rut, a trouble experienced with all such joints where the wheel traffic is considerable.

It is not apparent that an extra pitch, transversely, was needed for the gutter. The general contour of the street might have been maintained, as usual, to the vertical face of the curb.

It seems to the writer that the author and Mr. Tillson are correct in their objections to an absolutely plane surface for the pavement, although they differ from Mr. North in this respect; but quite as

serious an evil is the level surface resulting from the use of a circular-arc cross-section, with gutters of equal elevation. Referring to Section No. 12, it is seen that for 7 ft. at the center of the carriage-way the rise is only $\frac{1}{8}$ in. It is practically impossible to avoid depressions along the center of the street where so slight a rise is attempted. Mr. Andrews.

As to the amount of crown to be given a street with gutters of equal elevation, the writer prefers $\frac{1}{72}$ rather than $\frac{1}{100}$ of the width of carriage-way as giving sufficiently flat transverse slopes and as avoiding depressions, while the water is more rapidly brought to the gutters. The ratio $\frac{1}{72}$ is practically that used by the author, the radius of his circular segment then being nine times its chord. The variation between the circle and the parabola is so extremely minute that the cross-section may be termed circular with perfect propriety. The ordinate of the parabola is $y = \frac{x^2}{2r}$, while the ordinate of the circular arc is $y = \frac{x^2}{2r} + \frac{x^4}{8r^3} + \frac{x^6}{16r^5} + \text{etc.}$ In the author's example, for the maximum ordinate, $x = 18.67$, $r = 9 \times \text{width} = 336.06$, sufficiently near (the author gives $r = 335.30$). For the parabola y will be 0.5186, while the second term, $\frac{x^4}{8r^3}$, increases this only by 0.0004, the third term being too small to be considered.

The writer, a number of years ago, abandoned the circular-arc form of cross-section and has adopted, for some 20 miles of pavement on concrete foundation, a form intermediate between the circular arc and straight lines forming chords of half the arc.

According to Thomas Codrington, in his article on roads,* this form is used in London, and Mr. Hankinson's proportion of 8 to 5, as that which the crown bears to the ordinate at the quarter, also agrees with this cross-section. A useful comparison between this form and the circular arc can be made by considering the rates per cent. of the slopes at different parts of the transverse section. If R represents the ratio of width to crown, 72 : 100, etc., and the carriage-way is transversely divided into eighths; then the rates per cent. in the four divisions lying between the center and the gutter, starting at the center, are: For the circular arc, $\frac{50}{R}$, $\frac{150}{R}$, $\frac{250}{R}$ and $\frac{350}{R}$, and for the improved form mentioned, $\frac{125}{R}$, $\frac{175}{R}$, $\frac{225}{R}$ and $\frac{275}{R}$, respectively. For example, with $R = 72$, the slopes of the circular arc are 0.695%, 2.08%, 3.47% and 4.86%, while the preferred cross-section has slopes of 1.74%, 2.43%, 3.13% and 3.82%, being less flat in the center and flatter at the gutters than the circular arc. By thus considering the rates per cent. of different portions of the cross-section, it is easy to perceive the effect

*Encycl. Britannica.

Mr. Andrews. of unequal heights of gutters if the slope of the line between them is expressed in the rate per cent.

It would be interesting to know from the author how nearly he succeeded, practically, in securing the cross-sections called for in his theoretical investigations. The writer has found it quite impossible in dense, wet clay to form the subgrade to exact shape. A 10-ton roller will make waves and depressions both longitudinal and transverse, yet the concrete and pavement will stand well when the work is complete. In the writer's practice the curbs are first placed, and, by means of a cord stretched between them and measured offsets, the subgrade is approximately formed and is then rolled. The cord is again used and iron rods are driven at the eighths of transverse width; the top of the concrete is marked on these with chalk and the subgrade is then shaved off, generally, or filled up, rarely, until it is exactly the proper distance below the chalk marks. Concrete is then spread and, afterward, the iron rods are pulled up. For a brick pavement fine sand is spread on the concrete, and it is then struck by means of a template resting on rollers running on the curbs. This template is formed with considerable exactness and can be used on widths of carriage-way up to 36 ft. For greater widths a template of half the width of the carriage-way is used, running on one curb and on a timber laid temporarily in the center of the street. These templates have two rollers at each end; the faces of the rollers are slightly wider than the curb thickness. They are swivelled so that one end of the template can be drawn in advance of the other, thus accommodating a varying width of carriage-way of as much as 6 ins. The sand cushion is formed with great nicety by this means; it is then dampened, the bricks are laid and afterward rolled with a 5-ton roller. The pavement is then carefully inspected and imperfect bricks are replaced. The sand cushion is hard and compact, and the contact with the bricks is perfect. The joints are then grouted with Portland cement and sand in equal parts. The writer has laid 13 miles of brick pavement in this manner and has observed no rumbling or distortion such as has been the cause of complaint in some cities. The bricks used have been red shale in all cases.

Mr. Owen's suggestion of a depression in the center of the street is worthy of serious consideration. The writer has often been impressed with the desirability of such a form of cross-section when for several months the gutters are filled with snow and ice, and in times of thaw all drainage is necessarily in the center of the street. Except in the case of alleys where there are no sidewalks the writer has, however, never used a cross-section throwing the water toward the center of the carriage-way.

A low retaining wall $1\frac{1}{2}$ to $2\frac{1}{2}$ ft. high has been used with advantage

in place of a curbstone on the high side of a carriage-way. In Troy, N. Y., there exists such a wall nearly 6 ft. in height. Mr. Andrews.

In the improvement of the streets of the older and of the hilly cities the municipal engineer is often in despair at the difficulties arising from the original and grossly improper formation of the street. The author is to be congratulated on the comparatively easy nature of the problem and on the readiness of the inhabitants, as commendable as unusual, to co-operate with him in the carrying out of his plans.

ROBERT P. WOODS, Jun. Am. Soc. C. E. (by letter).—It appears probable that methods of street construction may vary in different parts of the country and still be suited to their respective localities and attending circumstances. Mr. Woods

The method of shaping unbalanced cross-sections recommended by Mr. Tillson was used by the author on Miami Street (Sections 1 and 2), and would have been used throughout the improvement, but that its continued application would have produced results apparently more unsatisfactory than the double curb.

The five sections as rearranged by Mr. Tillson are not as practical as might appear from a casual inspection of them singly. In his Section No. 2 the east gutter on Miami Street is raised 10 ins., leaving but 2 ins. fall in a block of 280 ft. This, obviously, would not answer.

By raising the west gutter on Wabash Street 1 ft., as shown in his Section No. 5, the grade of the gutter at the alley north of Canal Street would be 1 in. above the sidewalk.

In his Section No. 7 the slope of the south walk on Market Street is lessened to 0.20 ft., which is sufficient for that walk; but the longitudinal grade of the west walk on Wabash Street is not as great as the Market Street walk, and he thereby reduces the cross-slope of the Wabash walk to 0.08 ft. or $\frac{1}{12}$ in. per foot, which is not enough.

The predominating slopes used by Mr. Tillson in the roadway revisions appear to be far too slight for the existing conditions in Wabash, and from this standpoint the author believes they are not acceptable.

The author's Sections Nos. 7 and 8 show the slope of the roadway to be from one gutter to the other, but in connection therewith it should be noted that either of these sections is on a warped or boned-in section, and was exhibited merely to show a partial detail of the manner in which the Market Street grade was merged into the hill-side grade of Wabash Street. At no place in the improvement does water drain transversely of the roadway from one gutter to the opposite; the longitudinal grade of the north gutters on Market Street, at the warped sections cited, each being 3%, the water is carried to them.

It has been suggested that the extra step should have been placed at the building line, or at the area line. To illustrate the local feeling

Mr. Woods. concerning such location, it may be stated that the original grade on the north walk of Market Street from Wabash Street westward 324 ft. was flush with the lower curb; but before this particular walk was constructed the nine abutting property owners signed a petition asking the Common Council to raise the grade by means of the double curb, and at the expense of the abutters. This petition, which had been presented after most of the double-curb work had been constructed, would lead one to presume, that from a local standpoint the curb was not considered "expensive, unsightly and dangerous," as indicated by Mr. Tillson.

The total extra cost of the improvement to the abutting property owners adjacent to the double curb was but 10 cents per foot more than to those along the single curb.

Mr. Evans believes the double curb would be a repository for filth, yet during the nine months that have elapsed since the construction it has not been, nor should it become so, for should the merchants fail to sweep the curb when they sweep the walk, the drainage from the walks, upon the smooth cement surface of the curb, which has a cross-slope of $\frac{1}{4}$ in. per foot, would be ample to keep it in a sanitary condition.

Mr. Owen's preference for a single high step at the curb, when it is necessary, is well founded, where there is to be much transfer of heavy merchandise; but in Wabash the freight is transferred from the wagons to the buildings in the 16-ft. alleys.

It was the peculiar local conditions surrounding the district improved that caused the author to arrange the double curb as used, and the results are decidedly satisfactory.